Designing and Evaluating Interfaces for the CAPTAIN MEMO Memory Prosthesis

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***Abstract*— This paper presents the design, development and evaluation of the interfaces of the CAPTAIN MEMO memory prosthesis that target mainly individuals who are showing early/moderate signs of Alzheimer's disease. One of the major barriers that hinder Alzheimer's disease patients using software application is its complex interface. In this paper, we present a set of design guidelines for accommodating changes which accompany the Alzheimer's disease. Based on these guidelines, we develop the interfaces of the CAPTAIN MEMO memory prosthesis that meet the special needs of Alzheimer's disease patients. The developed interfaces present the advantages that they are user-friendly, multimodal, enjoyable and configurable. The objective of this work is to promote accessibility to the target user. The evaluation of the interfaces' accessibility is carried out with 24 Alzheimer's disease patients who are living in an assisted living environment in Sfax-Tunisia. The primary results show that the majority of the users are almost satisfied with the developed interfaces.**

Keywords- alzheimer's disease; memory prosthesis; user inetrfaces; multimodalities; speech-to-text; spoken interactions; touch; adjustable interface; design for all.

I. INTRODUCTION

This paper presents user-friendly, multimodal, enjoyable and configurable interfaces that are developed for the CAPTAIN MEMO memory prosthesis [1].

In the VIVA project [2] ("Vivre à Paris avec Alzheimer en 2030 grâce aux nouvelles technologies"), we are proposing a memory aid, called CAPTAIN MEMO, to help users to palliate mnesic problems. It target mainly individuals who are showing early/moderate signs of AD (Alzheimer's Disease).This prosthesis aims to enhance the well being of AD patients' lives.

AD patients present own characteristics that differ from other user groups, parts of them are related to AD and the other parts are related to the normal effects of aging. These characteristics impair AD patients to use standard user interface. Thus, the design of the user interfaces of the CAPTAIN MEMO memory prosthesis should suit AD patients' specific needs to be accessible and easily used; becoming user-friendly interfaces. The CAPTAIN MEMO memory prosthesis tends to follow the "design-for-all" philosophy [1] that means considering not only intelligent healthy users who master technologies, but everybody of all ages and abilities, including the elderly suffering from AD.

The CAPTAIN MEMO memory prosthesis provides multimodal interfaces. Indeed, the interfaces' interactions are not restricted to traditional modalities. We add other modalities: audio, speech recognition and touch.

We add humor and fun to the interfaces in order to make it attractive and seduce more AD patients to use the CAPTAIN MEMO memory prosthesis frequently.

The interfaces are adjustable since the user can adjust text size and volume themselves. They can be adapted to the user's visual and auditory abilities.

The remainder of this paper is structured as follows: Section II gives an overview of the CAPTAIN MEMO memory prosthesis. Section III reviews the main characteristics of AD patients, including the changes related to AD and the changes related to the normal effects of aging. Section IV proposes a set of design guidelines which should be taken into account for designing interfaces dedicated to AD patients. Section V describes the implemented interfaces. In Section VI, we present the evaluation of the interfaces that it is conducted on 24 AD patients. In Section VII, we discuss some related work and describe how our work differs from the existing ones. Finally, in Section VIII, we conclude and we give some perspectives.

II. OVERVIEW OF THE ONGOING CAPTAIN MEMO MEMORY PROSTHESIS

This section gives an overview of the ongoing CAPTAIN MEMO memory prosthesis for persons who are showing early/moderate sign of AD.

A. Basic Functionalities

The CAPTAIN MEMO memory prosthesis supplies a set of services indoor and outdoor. We categorize these services into two categories: "*Life Enhancing Services"* and *"Memory Refresh/Exercising Service".*

1) Life Enhancing Services

Life enhancing services can be categorised into the following four services: "*Family/Entourage Show", "Calendaring", "Diary" and "Event Show".*

The first module is called "*Family/Entourage Show*". It reminds AD patients of their family members and their surroundings. It is also devoted to "remember things about people", i.e., retrieving a person by navigation in the family/entourage tree, retrieving a person according to criteria, retrieving a person facing the camera, retrieving

 ISBN: 978-1-61208-468-8

information about a person (name, family or conviviality relationship, age, preferences, gifts exchanged, favourite meals, recent events, shared events, etc.).

The second service is called "*Calendaring*". It reminds AD patients of all daily activities that should be performed. The events can refer to information stored in the prosthesis such as photos to help the patient recognize the person he needs to talk to or the place he needs to go to. The reminder / alarm can be set to be passive or active.

Another service is called "*Diary*". It allows AD patients to document their important events and personal details (an electronic memory). The stored data may be selectively updated, retrieved and displayed at the convenience of the user. AD patients may interrogate this electronic diary and read what they have written before to refresh memory.

The last service is called "*Event Show*". It allows AD patients to take photo and video e.g., photo and video of people, places and events. The user is then given a chance to tag the photo or video with phrases that reminds them of the subject. AD patients can go back to the stored information as frequently as needed.

2) Memory Refresh/Exercising Service

This service is called "*Biographical Quiz*". It aims to refresh the AD patients' memory by quizzing the patient about information related to their family, surrounding, event and so on, e.g., What is the favourite meal of John? What's your son's favourite animal? Is Alice black-haired? Does Robert wear clothes (Adding humor)? What does your mother work? After each question, the patient is asked to give the correct answer. The highlight of this service is that each patient has his/her own collection of questions linked to his/her private life.

B. System Architecture and Used Technologies

In this section, we present the system architecture and the technologies used to implement the CAPTAIN MEMO memory prosthesis.

The CAPTAIN MEMO memory prosthesis is a semantic web application based on RDF ontologies and implemented in J2EE platform. We use the Jena API [3] and the SPARQL language [4].

The CAPTAIN MEMO memory prosthesis is a distributed multitiered application, based on MVC [5] in J2EE platform. Figure 1 shows the architecture of the ongoing system.

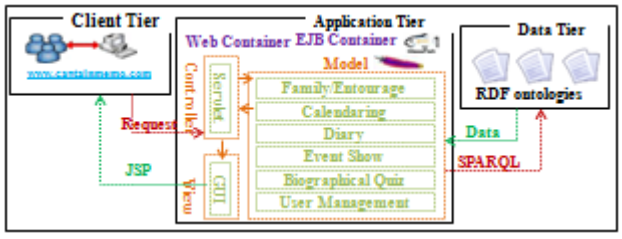

Figure 1. System architecture.

The CAPTAIN MEMO prosthesis consists of three tiers as it is distributed over three different locations: the client machines, the J2EE server machine and the data machine. We use Glassfish [6] as J2EE server and Apache [7] as HTTP server.

The CAPTAIN MEMO memory prosthesis follows the MVC design pattern. The Model components represent the business logic (EJB). The View components (JSP) represent the interface that displays the processing results of the model components. The Controller (Servlet) manages the coordination between the Model and the View.

III. CHARACTERISTICS OF ALZHEIMER'S PATIENTS

In this section, we discuss expected changes which accompany the AD. In fact, interfaces devoted to AD patients are not that common [8]. The difficulty in using interfaces is one of the reasons why AD patients are not comfortable to use computer or software [8]. The design of the interfaces should suit the user's needs [8][9] to be accessible and easily used. To adapt the interface to their needs; we first have to know their main problems. Compared to young healthy people AD patients suffer from AD-related changes and age-related changes, as shown in Figure 2.

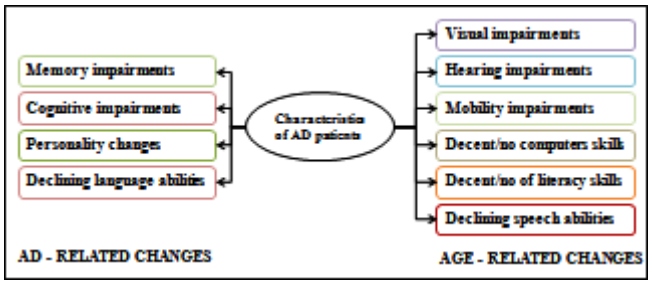

Figure 2. Characteristics of AD patients.

A. Alzheimer's Disease-Related Changes

Disabilities related to AD can be grouped into four groups: memory impairments, cognitive impairments, personality changes and declining language abilities.

Memory impairments - One of the most common symptoms of AD is memory loss [8][10][12][14], especially short-term memory or forgetting recently learned information. The semantic information is normally preserved in long-term memory [15], e.g., history and languages.

Cognitive impairments - The cognitive ability is one of the functions to decline due to AD [8][12]. Cognitive is the ability to generate ideas, to think, to remember and to focus on. AD causes a decrease in cognitive abilities such as the level of intelligence, speed of information processing, ability to learn, reasoning, judgment, attention ability [16], ability to solve problem and concentration ability [16].

Personality changes - AD patients experience changes in personality. The National Alzheimer's Association estimates that up to 40% of patients experience depression. They are anxious about technology [17] and may refuse to learn [18].

Declining language abilities - AD patients exhibit declining language abilities [14]. Indeed, early stage AD patients may substitute words that have similar meaning.

Moderate stage AD patients have increased difficulty in naming things.

B. Age-Related Changes

Most AD patients are elderly and thus have the usual limitations associated with aging [15]. Disabilities related to age can be grouped into six groups: visual impairments, hearing impairments, mobility impairments, decent/no computers skills, decent/no of literacy skills and declining speech abilities.

Visual impairments - Old people experience a decline in their vision [10][16][19]. Aging is accompanied by a loss in visual acuity [8][10][20], decline in peripheral vision [19], decrease in dark adaptation [22], impairment of near-focus [15] including a computer screen [19], and decline in color sensitivity [17][19][22]. The Alzheimer's association reports that over 60% of AD patients experience a decline in at least one visual capacity [14].

Hearing impairments - Aging is related to declines in auditory acuity [15][16][19][20][21][22]. At the age of 65 years, about 50% of men and 30% of women experience hearing loss [24]. Old people may suffer from another complaint that they can hear people talking, but they can't make out the words [15]. They may also find it hard to understand synthetic speech [22].

Mobility impairments - The mobility decline with aging [10][16][17][19][20][21][22]. Seniors with manual dexterity impairments have difficulties to operate with the mouse and keyboard. It is difficult for them to position the cursor if the target is small, and they have problems with control of fine movements. Because of the reduced motor functions, more errors occur during fine movements [16].

Decent/no computers skills - The elderly are not proficient in computer use and related technologies [17][20].

Decent/no literacy skills - The illiteracy rate of seniors aged 65 years and above are important. Besides, many seniors are literate; however they have basic literacy skills. They may not fully understand text-based information. Most seniors have difficulties with typing; they may forget how to write words.

Declining speech abilities - Speech ability declines with aging [16]. Old people have problem in pronouncing complex words. Therefore, the speech input can be limited by voice tremors.

Based on these changes, we strongly believe that AD patients will face difficulties if we adopt standard interfaces into the CAPTAIN MEMO memory prosthesis. Thus, in the next section, we propose a set of design guidelines for accommodating these changes.

IV. DESIGN GUIDELINES FOR DEVELOPING INTERFACES FOR ALZHEIMER'S PATIENT

In this section, we propose a set of design guidelines which should be taken into account for designing interfaces dedicated to AD patients. The guidelines are grouped according to changes identified in the previous section. Ten groups of accessibility guidelines are created. They are categorised into AD-related guidelines and age-related guidelines.

A. Alzheimer's Disease-Related Design Guidelines

This section proposes some practical design guidelines to accommodate the AD-related changes identified before.

Memory impairments - The interface should give a feedback after every action [10], use short messages [10][20], support users in their interaction e.g., through a speaking front end [20] and use consistent navigation throughout the website.

Cognitive impairments - The information should be summarised and categorised semantically into short categories. The headlines should be displayed on the top of the interface [18]. Image and icon should be simple, meaningful and easy to understand [18]. Text should be clear and avoid abbreviation [19][20]. Links should be underlined to make them identifiable. The design should be simple [15] and only main information should be displayed [21][22]. The interface's distracting elements should be avoided [18][21]. Multimodal solutions improve the accessibility and facilitate the comprehension [10][11][22].

Personality changes - It is recommended to add fun and humour to the interface [23]. The wordings should suit the adults' semantic field [13]. Error feedback messages should make it clear that the user is not the cause of the error [18].

Declining language abilities - We recommend reducing the need for keyboarding or entire text input.

B. Age-Related Design Guidelines

Some practical design guidelines are mentioned in this section, according to age-related changes.

Visual impairments - the interface should have an appropriate size of design elements and text [11], use at least 12-points to 14-points type size [16][21] and 16-points for headings, avoid large blocks of bold or underlined text [19], use a left aligned text [18], put the ability of zoom in the interface [15][18][22], use a sans-serif font type [19] and a medium face type [18], use soft colors [19], avoid decorative fonts [10][15], maximize the contrast between foreground and background colors [10][18][19][21] and write main body in lower cases.

Hearing impairments - It is recommended to use, by default, higher sound [18], increase the duration of sound signal [18] and place a volume control in an easy to find spot [10][18]. The auditory information should be spoken slowly [10], pause slightly after each statement [15], use male voice [18][21] and use natural speech [15][22].

Mobility impairments - The design should contain large targets for accurate selections [13], use an audio supported menu [11], avoid the use of scrolling [18][19] and pull-down menus [19] and use touch screens [16][18][21].

Decent/no computers skills - Special assistance in terms of navigation should be given [9] e.g., providing previous/next links [19], showing the current location and providing a web site map. It is important to have an easy way of inserting special characters [11] e.g., the "@" character.

Decent/no literacy skills - It is recommended to use graphical metaphors or sounding when users cannot read easily [10][22], identify buttons by icons and labels [13], minimize the use of keyboard [13] and use the speech-to-text mode for typing.

 ISBN: 978-1-61208-468-8

Declining speech abilities - Acoustic models specialized for elderly should be used for the speech-to-text mode [21].

Based on these design guidelines, we develop the interfaces of the CAPTAIN MEMO memory prosthesis.

V. THE DEVELOPED INTERFACES OF THE CAPTAIN MEMO MEMORY PROSTHESIS

In this section, we present the developed interfaces of CAPTAIN MEMO prosthesis for persons who are showing early/moderate sign of AD. The developed interfaces are user-friendly, multimodal, enjoyable and configurable.

We use a sans-serif font type (Arial), a medium face type and by default, 12 pt to 15 pt type size for displayed texts and 25 pt for headings. We use a black font on orange background to maximize the contrast between foreground and background. The main body is written in lower cases. We provide large buttons and images. Graphical metaphors or images are used to facilitate understanding text-based information, e.g., the use of the key metaphor associated to connection step in Figure 3.

Figure 3. Graphical metaphors to facilitate understanding text information.

We put the ability of zoom in the family tree. We provide large nodes identified by using pictures and labels, as shown in Figure 4. To ensure the simplicity of the design, we display details only on demand. We display the details of the node which is selected. Clicking on a node allows it to be bigger and distinguishable from the others.

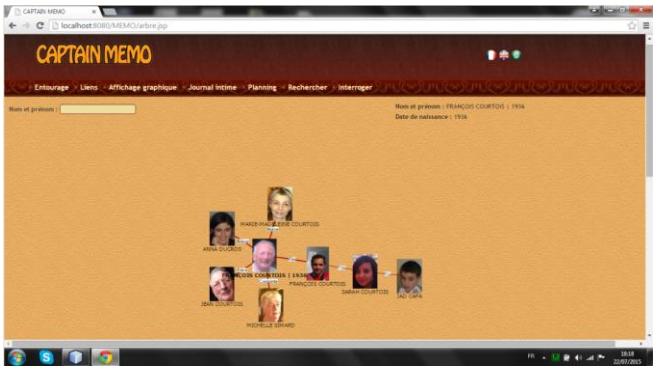

Figure 4. Identifying nodes of the family tree by using pictures and labels.

Different modalities are employed. The input modalities include speech-to-text, touch and pointing device + keyboard. The output modalities include vision and voice/audio.

We provide two modalities for typing: the traditional mode and the dictation or speech-to-text mode. We give the possibility of alternating between modalities. We reduce the need for keyboarding or entire text input. We provide choices to select from a dropdown list as possible.

We provide feedback after every action. We use two modalities of feedback: vocal and textual. The text and audio feedback have the same message. We use easy to understand and short messages. We use different tones for errors and successful entries.

We add an old parrot to the interfaces, which is known for intelligence, fun and especially for the ability to imitate human voices. We resort to funny sentence for both textual and vocal message. We use droll emoticons.

We add an auditory background to the interfaces in order to support the users in their interactions. We use a male voice and natural speech. We use, by default, higher sound for delivering the auditory information. The auditory background can turn on or off.

The interfaces are adjustable. We let the users adjust text size and the volume themselves.

The interfaces are implemented in three languages: French, English and Arabic. Figure 5 shows an interface presented in Arabic language.

Figure 5. An interface presented in Arabic language.

Finally, we have to evaluate the developed interfaces with AD patients. The next section elaborates the results.

VI. TESTS AND EVALUATION

The evaluation of the interfaces' accessibility and ease to use is carried out with 24 AD patients who are living in an assisted living environment in Sfax- Tunisia (Street Manzel Chaker km. 8). The participants have an average age of 64 years – the youngest is 55 years old and the oldest is 78. Most patients have AD in early/moderate stage. Their profiles are summarized in terms of age, stage of AD, difficulties in vision/hearing, computer skills and literacy skills.

 ISBN: 978-1-61208-468-8

This study was performed from July 2015 for about two months. Tasks were performed on tablet PC. A stylus pen is used to input commands to the touch-screen. The questionnaire covers five dimensions which include: "*Overall Reaction*", "*Visibility*", **"***Speech-to-text*", "*Terminology*" and "*Auditory Background*". A five point scales are used: strongly disagree (1), disagree (2), neutral (3), agree (4) and strongly agree (5). Table 1 summarizes the results and the mean score for each dimension.

TABLE I. SUMMARY OF THE QUESTIONNAIRE'S RESULTS

Question	(1)	(2)	(3)	(4)	(5)	Mean
OVERALL REACTION (overall mean=4)						
Are the interfaces easy to use?		3	3	5	9	4
Is it easy to learn to use the interfaces?		7	3	10		3,15
Are the interfaces funny-to-use?			1	3	16	4,75
Are you satisfied about the interfaces?		3	3	3	11	4,1
VISIBILITY (overall mean=4,75)						
By default, can you read the main body?		4		4	12	4,2
By default, can you read headlines?				2	18	4,9
Is the ability to adjust text size useful?					20	5
Are images large enough?				2	18	4,9
SPEECH-TO-TEXT (overall mean=3,8)						
Is the speech-to-text mode helpful?	5			4	11	3,8
TERMINOLOGY (overall mean=4,72)						
Are the command names meaningful?				2	18	4,9
Icons are easy to understand?			2	3	15	4,65
Is the use of text labels improves the icon's interpretation?					20	5
Are error feedbacks helpful?		4	2	1	13	4,15
Are informative feedbacks straightforward?				2	18	4,9
AUDITORY BACKGROUND (overall mean=3,825)						
Is the voice speed reasonable?	6			10	4	3,3
Are vocal feedbacks useful?	6	2			12	3,5
Are spoken interactions helpful?	6	2			12	3,5
Is the ability to adjust volume useful?					20	5

Only 20 participants fully complete all tasks. The others just start the first test. They say that they are too old and have no motivation in learning a new technology. Those participants are the oldest with AD in moderate /late stage. They have no computer skills. We call them "patient-restricted users".

The overall mean score of the 5 dimension is between 3, 8 and 4, 74. Overall, the results indicate that the users are almost agreed that the developed interfaces are accessible and easy to use.

55% of all participants are strongly satisfied with the system. They say that they will use the CAPTAIN MEMO memory prosthesis frequently. Those participants suffer from AD in early stage, familiar with computers and have good literacy skills.

25% of all participants say that it is easier for them to type with a virtual keyboard; since their voice volume is not enough to be captured by the device's microphone. Thus, in the next iteration, we will use acoustic models specialized for elderly persons for the speech recognizer. Illiterate participants are very satisfied with the dictation modality.

30% of all participants ignore totally the speaking front end since they don't understand words. Thereafter, in the next version, we will use slower voice speed.

VII. RELATED WORK

In this section, we review some software application developed to support AD patients such as COGKNOW [25], AP@LZ [26], BACKUP MEMORY [27] and ARCUS [28]. COGKNOW and AP@LZ provide reminders to do specific activities according to a schedule. BACKUP MEMORY helps AD patients remember their families and/or surrounding. ARCUS is a virtual name directory that allows searching for names using cues. Table 2 gives a general comparison between the user interfaces of the cited applications.

TABLE II. COMPARISON BETWEEN INTERFACES OF APPLICATIONS DEDICATED TO ALZHEIMER'S PATIENTS

		COGKNOW (2007)	AP@LZ (2010)	ARCUS (2012)	BACKUP MEMORY (2015)	CAPTAIN MEMO (2015)
Visibility	Simple layout	Yes	Yes	Yes	Yes	Yes
	Maximised contrast	Yes	Yes	Yes	No	Yes
	Readable text	Yes	Yes	Yes	No	Yes
	Large buttons	Yes	No	Yes	No	Yes
	Large images	Yes	No images used	No images used	No	Yes
Modalities		Touch, vision, audio.	Vision, touch	Vision, touch.	Vision, touch.	Vision, touch, audio, speech-to-text, keyboard + mouse.
Fun		No	No	No	No	Yes
Configuration		No	No	No	No	Yes

Compared to related work, the developed interfaces of the CAPTAIN MEMO memory prosthesis provide more features than the other applications. In fact, only COGKNOW and CAPTAIN MEMO provide a good management of the screen's elements. Second, the developed interfaces provide more modalities, which can increase the chances of comprehension. Finally, only our work allow user setting the volume and the size of the font and add fun to seduce AD patient to use frequently our memory prosthesis.

VIII. CONCLUSION AND FUTURE WORK

This paper presented the developed interfaces of the ongoing CAPTAIN MEMO memory prosthesis, which is developed to assist individuals who are showing early/ moderate signs of AD to palliate mnesic problems. So, at the beginning, we discuss the expected changes related to the AD and the aging process. Based on these changes, we

 ISBN: 978-1-61208-468-8

believe that the interface plays a big role to ensure that AD patients can use the CAPTAIN MEMO memory prosthesis easily. To accommodate those changes, we propose a set of design guidelines for interfaces dedicated to AD patients. This set of design guidelines covers the main AD-related changes and age-related changes that might affect the accessibility of the interfaces. Based on these design guidelines, we develop the interfaces of the Captain Memo memory prosthesis. The developed interfaces present the advantages that they are user-friendly, multimodal, enjoyable and configurable. Afterward, a user satisfaction evaluation of the interfaces is carried out with 24 AD patients. The results confirm that the developed interfaces are easy to use and funny to use. The majority of the participants say that they will use our prosthesis frequently. Finally, we review some related work and demonstrate how our work differs from the existing ones.

Future works will be mainly devoted:

- To integrate acoustic model specialized for elderly persons for the speech recognizer;
- To use slower voice speed for the auditory background;
- To add the haptic modality in order to offer a tactile feedback for the user ,which is a vibration that occurs when the user selects a button with his/her finger;
- To add an audio supported menu. Speech should work not only for dictation when writing a message, but also for command;
- To authenticate the users using the facial recognition modality;
- To evaluate the CAPTAIN MEMO memory prosthesis with memorizing test.

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 ISBN: 978-1-61208-468-8